

Report for 2004IA63B: Vegetative Filter Education and Assessment in the State of Iowa

There are no reported publications resulting from this project.

Report Follows

Vegetative Filter Education and Assessment in the State of Iowa

Steven K. Mickelson, Matt Helmers, Kapil Arora

Problem and Research Objectives

Reduction of sediment and nutrients in surface runoff to rivers and lakes is important to Iowa's initiative to reduce the number of impaired water bodies. Vegetative filters help to reduce the deterioration of the surface waters through retention of the sediments and nutrients from surface runoff from agricultural fields. Vegetative filter strips (VFS) have been shown to be most effective for shallow, uniform surface runoff conditions, but it has also been shown that, in the case of heavy overland flows, the flow concentrates and only a portion of the vegetative filters proves to be effective in sediment and nutrient retention in the filter. Determining the most important design considerations for VFS is important for maximizing the water quality benefits for the VFS. Therefore, the on-site assessment of existing vegetative filter strips to examine and document critical design criteria is highly significant. It is also important to extend the findings and knowledge found in the field assessment to the stakeholders and upcoming generation so that they implement these designs and protect the environment. Therefore, the following objectives are considered important to be achieved in relevance to the existing scenario. The objectives include:

1. Development of an assessment tool for evaluating the effectiveness of VFS using past and current research literature findings;
2. Identification of VFS sites for in-field data collection and assessment;
3. Education of grade school, junior high, and high school students on VFS performance and surface water runoff issues related to water quality and biodiversity;
4. Assessment of the performance of VFS in a local watershed within Iowa using site assessment tools developed by this study and students educated through the project; and
5. Calibration and validation of a computer model (VFSSMOD) for use in education related to the effectiveness of VFS in Iowa.

Methodology

Using data from past and current research projects on VFS, an on-site assessment tool will be developed to evaluate the performance of Iowa's VFS in key impaired water bodies. The major component of this study constitutes assisting grade school, junior high, and high school students in evaluating current VFS in an impaired watershed(s) close to their location. These training sessions will help the students to better understand the processes and impacts of nutrients from agriculture on water quality and the impact of sediment accumulation on aquatic life in lakes and streams. The Rock Creek Watershed next to Newton, Iowa has been selected by the research team. This site was selected since it was in the extension Agricultural Engineer's (Kapil Arora) region and due to the ease of collaboration with the local NRCS county office and the local educators. The students will make an efficient site evaluation with the guidance of the field staff and research team. The site evaluation will include the following parameters related to the filter strips:

- Vegetative filter length and width
- Slope and shape of the filter
- Type of vegetation
- Uniformity/space distribution of vegetation
- Tiller count
- Area ratio (contributing area to filter area)
- Rill and gully erosion evidence/measurements
- Residue cover of upland field
- Presence of drainage tile
- Evidence of wildlife
- Evidence of stream bank stability and/or instability
- Visual evidence of flow patterns (residue strips)
- Biomass/area

Validation checks will be made for the assessment at each subwatershed site within the Rock Creek watershed by the research team. The data from the site evaluations will be used to develop an assessment tool in Geographic Information Systems (GIS). This software will combine the site evaluation data of each point on the filter strip into layers of information at that point on the map of the watershed to give a better understanding of the runoff hydrology at that point. The technique of Digital Elevation Model (DEM) will be employed for the digital representation of the topographic surfaces as a regular grid of spot heights. It will also help us to estimate the elevation at different points in the watershed, hence helping in the estimation of the slope at various places. DEM will also help to identify the sinks in the drainage area, generate flow accumulation and flow direction in the watershed from which the drainage/stream network of the watershed can be established. This assessment tool will help to analyze and quantify the performance of the filter strips towards the prevention of surface water pollution.

We will also integrate the use of a simulation model known as VFSMOD (developed at North Carolina State University) to model VFS benefits under various hydrologic conditions with the help of data on rainfall, topography, land use, land cover, etc. The simulation model's graphical representation of study results will also prove to be an efficient educational tool for the high school students. High schools in the vicinity of Rock Creek Lake Watershed have been contacted, including the Grinnell High School FFA and Newton Senior High School FFA. Both FFA chapters have shown keen interest in participating in this project, and Structure of Intellect (SOI) at Thomas Jefferson Elementary in Newton has also agreed to participate. The students will fill out an Assessment Form (Figure 1) at a given VFS site. This will help students in their assessment of the filter strips. Qualitative measurements on the form will have supportive rubrics attached that more adequately describe various levels of quality related to a specific measurement. This learning activity is planned for September 2005. The team also met NRCS staff in September 2004 in regard to acquisition of the data related to the site. Information obtained through the surveys will be analyzed for flow patterns. As a result of this meeting, several potential sites were identified based on their vegetation growth, time (years since establishment), filter width, and drainage area served. Out of these sites, land owners of ten sites have agreed to partner in this project. The land

owners have agreed to provide access to the sites for the team to carry out their evaluations. The team visited the Rock Creek Lake Watershed in November 2004. During this visit, a few sites were evaluated for vegetation stand and visual observations of flow paths.

VEGETATIVE FILTER STRIP ASSESSMENT FORM	
Assessed By: _____	Date: _____
Location of investigation (State / County) _____	
Adjacent water body _____	
1. Type of land use or crop cover _____	
2. Nature of vegetation in the filter strips (cover type, average height of the cover, etc.) _____	
3. Slope of the field (%) _____	
4. Slope of the filter strip (%) _____	
5. Length and width of the filter strip _____	
6. Years of vegetative filter establishment _____	
7. Ratio of the buffer area to field runoff area _____	
8. Density of the cover in the filter (Thick, average, sparse) _____	
9. Flow observed (concentrated, uniform) _____	
10. Prevalence of the channelization /erosion _____	
11. Elevation of the filter strip with respect to the stream _____	
12. Stream bank stability _____	
13. Effectiveness of buffer strips in terms of water quality enhancement _____	
14. Vehicular traffic or wildlife evidence in Vegetative filter strips _____	
15. Degree of strip maintenance required time to time (describe briefly in terms of mowing for weed control, nutrient removal, inspection for stand establishment etc.) _____	

Figure 1. Rough Draft of VFS Assessment Tool

Principal Findings and Significance

The majority of the first year of this study has been spent on reviewing the key literature related to VFS for the purpose of designing the best on-site VFS assessment tool. Significant time was also given to developing the assessment tool, choosing the correct watershed, collecting in-field survey data, and setting up collaborations with the Newton educators. Therefore, objectives 1 and 2 have been completed and work is continuing this year on objectives 3–5. The following section is a summary of the findings from key literature sources that have been used in creating the VFS assessment tool.

The transport of sediments and the range of applied agrochemicals from agricultural fields into surface water bodies is one of the major environmental threats. This transport is a result of heavy rainfalls or huge amounts of overland flow. Controlling the amount of agrochemicals and sediments by planting close growing vegetation or tall, stiff grasses is

a significant management practice that helps reduce the transport of these substances to receiving waters. These VFS offer important advantages where runoff concentrates and are considered effective in filtering sediment and slowing down runoff velocity. These VFS, also called vegetative buffer strips, prove to be an impediment to the movement of suspended material in the runoff, hence promoting the settling of the suspended solids (i.e., sediments and applied agrochemicals). Therefore, it is important to assess the effectiveness of the VFS in removal of the sediments and nutrients from the runoff. The effectiveness of the strip is dependent on its width, types of vegetation, age, level of development, and many more factors. The quantification of the effectiveness of a VFS also helps to quantify the amounts of the sediments and the chemical runoff averted from the waterways.

Use of vegetative filter strips stands as an effective measure to filter pollutants from runoff leaving the agricultural lands. VFS displace land from crop production, hence, minimizing the filter area. Therefore, it's important to determine its effectiveness. One of the research studies of VFS involved experimentation in which UAN (source of N) and broiler litter were used as the nutrient sources (Margette et al., 1989). The study was conducted under the assumption that P movement is dependent on total soluble solids (TSS) transport; whereas N can move in soluble form more freely. Also, the soil taken was rich in P although no supplemental P was applied. The results showed higher losses of P during UAN tests and that those losses diminished as the number of tests progressed, while losses of TSS did not decrease. P losses generally decrease with an increased number of filter strips; as do TSS losses. The conclusions of the study indicated that the performance of the VFS generally diminishes as the ratio of vegetated to non-vegetated area decreases. Also, it was observed that the nutrient removals are affected as the number of runoff events increase.

In another study, strips of tall, stiff grasses were planted perpendicular to the slope to form a runoff and erosion control practice (Meyer et al., 1995). This offered an important advantage where runoff concentrates. If flow concentrates, the retarding and filtering effectiveness of the VFS is reduced. Stiff grass hedges are more resistant to erosion than VFS, as these have more robust stems, whereas narrow hedges promote sediment deposition primarily by slowing the runoff in ponded backwater. It was concluded from the experimentation that hedges retarded the flow and caused a hydraulic jump several meters upslope of the hedges, leading to the deposition of the coarser sediments just past the hydraulic jump. The formation of the hydraulic jump and sediment deposition enhanced the flow retardance and deepened the ponded flow. Sediment trapping resulted mostly from the upslope ponding by the hedges rather than the filtering action, so the physical characteristics of the different grasses such as stem density, diameter, stiffness, etc., were considered important primarily to the extent that they retarded flow. The sediment was observed to be trapped because it had sufficient settling time in the ponded flow and not because of its inability to pass through the voids in the grass. These results emphasized the effectiveness of the stiff grass hedges. Trapping effectiveness depended upon the size distribution of the sediment load rather than on the flow rate of the runoff.

Patty et al. (1997) studied the use of grassed buffer strips to remove pesticides, nitrate, and soluble phosphorus compounds from runoff water on three research farms. Grassed buffer strips were seen to be effective in restricting the pollutant transfer in runoff by large margins. The literature data and conclusions drawn showed that sowing perpendicular to the slope proved to be beneficial in reducing pesticide content in runoff and also indicated that all the conservation tillage systems reduced the herbicide runoff by an average of 60% when compared to moldboard plowing. Sorption of herbicides onto organic matter and vegetation in the grassed buffer strip was considered to be the active mechanism which contributed towards the effectiveness of the filter strips. It was also inferred from the experiment that a shorter time lapse between the application of fertilizer and rainfall leads to greater residues in runoff. Therefore, the ability of the grass buffer strips is best evaluated in the first events, when transfer probability is maximal.

Majed Abu Zrieg (2001) studied the factors affecting sediment trapping in VFS using a simulation study called VFSSMOD. A wide range of parameters was selected for studying the VFS performance such as filter length, filter slope, manning roughness coefficient, soil type, and characteristics of incoming sediments from adjacent fields. Computer simulations revealed that the length of the filter was the most significant factor influencing the VFS sediment removal efficiency, followed by the grain size of the incoming sediment. Higher amounts of silt particles in comparison to the clay particles were observed to be trapped in a particular length of the filter, which implies that the clay particles are trapped over greater lengths of filters. Manning's roughness coefficient, which increases with increase in land cover, land slope, and soil type, was seen to have a moderate effect on VFS performance in short filters.

Dosskey et al. (2002) studied that a concentrated flow of surface runoff from agricultural fields may limit the capability of the riparian buffers to remove pollutants. In other words, the concentrated flow may greatly limit the filtering effectiveness of the riparian buffers. Four study farms were considered and a method was developed for assessing the flow and evaluating the impact of the flow on sediment trapping efficiency. Sediment trapping efficiency was evaluated using the mathematical model that was largely based on the ratio of the buffer area to field runoff area. Results in the case of the gross buffer area were highly impressive in relation to sediment retention, as compared to that of the effective buffer area. This was because the field runoff contacted only a minor fraction of the gross area of the riparian buffer. It was noted that sediment trapping could only be improved by avoiding the concentrated flow, which is generally caused due to the deposition of soils from channelization activities within the buffer zone.

Lee et al. (2003) conducted a study to determine the effectiveness of an established multi-species riparian buffer in removing non-point source (NPS) pollutants from agricultural areas. Riparian buffers are being used as a best management practice to reduce the transport of NPS pollutants in agricultural runoff before they enter surface waters. The friction of soil surfaces can reduce the velocity of the runoff that consequently results in the sedimentation of particles, but riparian buffer vegetation and the layer of organic litter on the soil surface are much more effective in slowing the velocity of surface runoff (Correll, 1997). Triplicate plots were installed for this study

where each of the cropland source areas was paired with no buffer, a switchgrass buffer, and a switchgrass/ woody plant buffer located at the lower end of each plot. A significant negative correlation was observed between the trapping effectiveness of the buffers and the intensity and total rainfall of individual storms. Actually, buffers helped to reduce the mass transport of total N and total P in surface runoff from cropland due to the mechanism of infiltration. Infiltration provided the pathway for water and soluble chemicals to enter the profile, but suspended fine soil particles with adsorbed chemicals also entered the profile, thus decreasing the surface runoff and sediment transport capacity. Water samples that were collected from the field showed a significant decrease in surface discharge of runoff, sediment, and nutrients. Particle size distribution in the surface runoff changed through the buffers, indicating that there was a selective process in which large particles deposited prior to the small particles. It was observed that more than 90% of the sediment in the surface runoff from the buffered plots was in the <0.05 mm size. The differences in the amount of sediment and nutrients trapped by the various buffers were also attributed to the differences in cropping. The results therefore indicated that the selection of one buffer over the other should be based on the problems and conditions of each site.

Wu et al. (2003) conducted a study in order to compare the effectiveness of switchgrass and tall fescue filter strips in removing the dissolved copper pesticide from runoff flowing at 2.7L and 6.0L over 0.9m soil surface area. About 60% of the applied copper was removed by both the grasses from runoff at 6.0 L flow rate, whereas with the slow flow rate, grasses helped remove all the applied copper. Adsorption to soil appeared to be the primary mechanism of the removal of copper from overland flow. The copper adsorbed by the soil was calculated as the difference between the initial concentration and the equilibrium concentration. It was observed that major amounts were retained in the upslope one third of the filter strips, hence, reducing the dissolved copper in runoff by increasing its infiltration and its retention by soil. Results also emphasized that performance of the two grass species in promoting the infiltration mechanism varied with the flow rate.

Carpena R. Munoz and J.E. Parsons (2003) devised a design procedure for vegetative filter strips using VFSMOD-W. The objective of this procedure is to obtain the minimum filter length to achieve a desired runoff sediment reduction from a disturbed source area during a design storm of a given return period. VFSMOD, which is a main component of the VFSMOD-W, is a field-scale, mechanistic, storm based model developed to route the incoming hydrograph and sedigraph from an adjacent field through a VFS and to calculate the resulting flow, infiltration, and sediment trapping efficiency. A front end model, Unit Hydrograph, was developed and added to VFSMOD-W to generate the necessary source area design inputs for VFSMOD. The application of the design procedure for a particular area involved determining the size and duration of rainfall events, the range of source area conditions, and the lengths, slopes, and types of vegetative composition of the VFS. From the experimentation, the optimal filter lengths of 1–4 m for sandy soils and 8–44 m for clay soils were determined, but certain limitations were found as to the use of VFSMOD-W. VFSMOD handling of overland flow as sheet flow could pose problems when a filter is not properly maintained and

concentrated flow occurs within the filter. Filter trapping algorithms assume the formation of a regular sediment wedge deposition in the front of the filter. Also, the sediment trapping component considers no erosion and transport in the filter, which is not a problem with the well maintained filter. Therefore, the design procedure is only applicable to well constructed and maintained filters where uniform, shallow overland flow is present, which is a major limitation. The potential strength of the model is that the conservation practices in the disturbed area and filter characteristics can be studied together.

Majed Abu Zrieg et al. (2004) conducted an experimental investigation of runoff reduction and sediment removal by VFS. It was observed that the length of the filter up to 10 m had the greatest effect on sediment trapping, followed by vegetation density and inflow rate. The sediment trapping efficiency was observed to be decreased exponentially beyond 10 m. The sediment trapping efficiency was observed to increase with a decrease in inflow rates but in a non-linear fashion. Greater vegetation densities resulted in greater contact time between the soil and vegetation, resulting in less erosive power and less transport capacity of the runoff and, therefore, greater settling of the sediments and nutrients.

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